National Aeronautics and
Space Administration

21CCLC NASA STEM Challenge

Why Pressure Suits?

Facilitation Guide

FACILITATOR'S WELCOME

Dear 21CCLC STEM Facilitators,

Welcome to the 2014–2015 STEM Engineering Design Challenge Team! As part of this team, you will play an integral part in helping today's students become tomorrow's scientists, technicians, engineers, and mathematicians. Through the Engineering Design Challenge (EDC) students will participate in authentic learning experiences that will allow them to develop valuable skills through rigorous and engaging science, technology, engineering, and mathematics (STEM) content.

As a 21CCLC STEM facilitator, you are helping your students use their creativity, curiosity, and analytical thinking as they follow the **Engineering Design Process (EDP)**. Solving problems using the EDP will be key to the success of NASA's future engineering workforce.

Through the design challenge ***Why Pressure Suits?***, students will work in small teams of no more than four students to design a pressure suit or space suit that will protect a high-altitude pilot or an astronaut from the low-pressure environment of a near-vacuum or total vacuum environment.

The major real-world concepts of this challenge are:

1. **The Engineering Design Process (EDP)**
2. **Investigating how the human body reacts in the vacuum of space**
3. **Understanding the effects of a low-pressure environment on objects**

This Facilitator's Guide is designed to provide you with important information to use in planning and conducting the challenge. It includes simple explanations of relevant background information, clear step-by-step instructions, reflective data sheets, and concise rubrics for evaluation of student performance. You will be expected to use all of the included materials with your students. You can adapt the timeline to fit your classroom schedule.

NASA supports educators and facilitators, like you, who play a key role in preparing students for careers in STEM fields through engaging content. Thank you for helping us share this learning experience with your students.

Engineering Design Challenge Team

U.S. Department of Education
NASA Office of Education

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This challenge was adapted and content modified from "Why Do We Really Need Pressure Suits?" EP-2010-12-500-HQ.

INTRODUCTION

FACILITATOR'S OVERVIEW

The U.S. Department of Education and NASA's Office of Education worked together to create an **Engineering Design Challenge (EDC)** that gets students involved in using the **engineering design process (EDP**) to complete the Engineering Design Challenge.

The EDC serves as an authentic standards-based investigation that allows students to engage in the process of solving problems like today's scientists and engineers do. This EDC provides students with opportunities to gain tangible skills that are essential in STEM careers.

This guide is organized as follows:

1. Introductory materials – Establish a common basic level of understanding about the EDP and its relation to this challenge. The introductory materials also include an alignment to Next Generation Science Standards and the Common Core State Standards for Mathematics, as well as background information highlighting NASA's science and research related to Packing for the Moon.
2. Facilitator pages – Provide instructions for facilitators to use throughout the design challenge. Tools are also included in this section for you to use to assess student understanding throughout each step of the challenge.
3. Student challenge journal – Contains prompts and tools to guide students through the cycle of steps in the EDP while documenting their work for each step.
4. Support materials – Consist of information to supplement and enhance the EDC.

These user-friendly sections help you support your students as they work in teams to complete the EDC. At the conclusion, your students will be required to articulate the steps taken in the EDP in a video each team will create. Good luck as you help create the next generation of STEM professionals!

For more information and to access the Help Desk, visit the NASA STEM Challenges website at http://y4y.ed.gov/stemchallenge/nasa.

The Basics of Engineering Design

What is an engineer? Engineers are at the heart of every Engineering Design Challenge. Engineers are people who design and build things that we use every day. The video at the link below will explain the role of an engineer and can be shared with your students: http://youtu.be/wE-z_TJyzil. After viewing the video ask the students to describe what an engineer does.

Figure 1: Aerospace Engineer Chris Randall tests rocket parts and life support systems to ensure they work as planned. (NASA)

Figure 2: Simulation System Engineer Debbie Martinez works on developing a general aviation flight simulation software. (NASA)

What is an Engineering Design Challenge? An Engineering Design Challenge helps students understand the engineering design process. Students are presented with a challenge or problem and, using the process, work in teams to complete activities and experiments to develop solutions to the original problem. These challenges facilitate teamwork, problem solving, and brainstorming ideas very similar to what real-world engineers encounter.

Engineering Design Process

What is the engineering design process? The engineering design process is a cycle of steps that leads to the development of a new product or system. The cycle repeats and continuously refines and improves the product or system. In this challenge, students should complete each step and document their work as they develop and test their design. To do this, students need to perform each of the steps in the EDP and repeat the cycle, as often as time and resources allow, to develop the best end product. Some steps, like “Researching the need or problem,” will only need to be briefly revisited to confirm that teams are still on track. Other steps, like “Test and evaluate the solution,” will need to be completely redone.

THE ENGINEERING DESIGN PROCESS

STEP 1: Identify the Need or Problem – Students, working in teams; state the challenge problem in their own words. Example: How can I design a __________ that will __________?

STEP 2: Research the Need or Problem – Teams use resources, from the Internet, the library, or discussions with experts, to examine how this problem is currently being solved or how similar problems are being solved.

STEP 3: Develop Possible Solutions – Team members draw on their mathematic and scientific knowledge and brainstorm all the possible ways that they might solve the problem. They choose the most promising options and refine their solution by quickly sketching in two or three dimensions. Labels and arrows should be included to identify parts.

STEP 4: Select the Best Possible Solution(s) – Team members share their ideas and answer questions from the other team members. Each team discusses and records strengths and weaknesses from each design and determines which solutions best meet the original need or solves the original problem, possibly including features from more than one design. The team writes a statement that describes why they chose the solution.

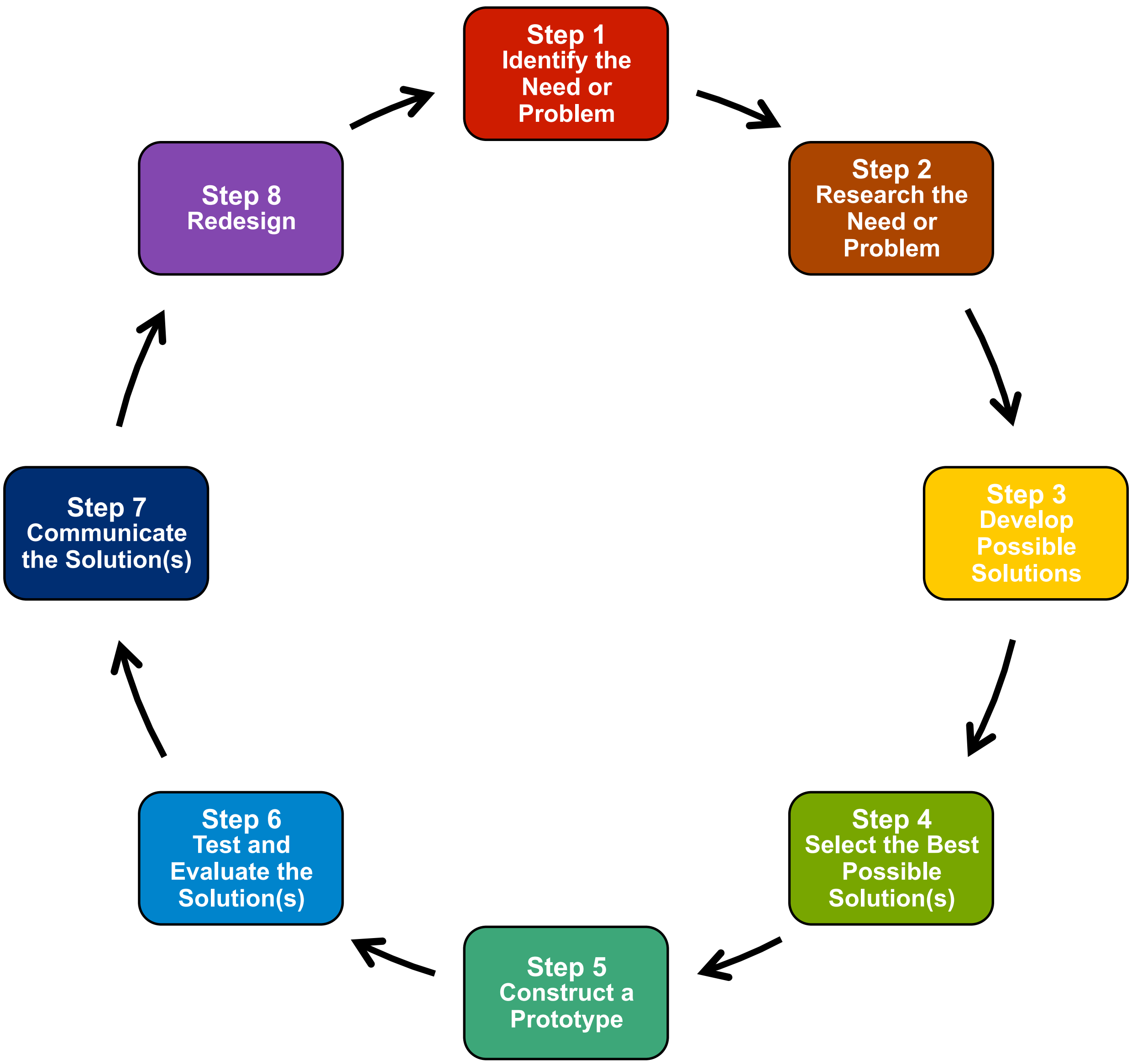
STEP 5: Construct a Prototype – Team members construct a full-size or scale model of the selected solutions in two or three dimensions. The facilitator helps to identify and acquire appropriate modeling materials and tools.

STEP 6: Test and Evaluate the Solution(s) – Teams test their models to determine how effectively they solved the need or problem. Data is collected to serve as evidence of their success or need for improvement.

STEP 7: Communicate the Solution(s) – Team members record and share what was learned about their design based on testing. They make a presentation that includes how their solution(s) best solved the need or problem and any improvements that could be made. They could ask students from other teams to review the solution and help identify changes.

STEP 8: Redesign – Team members consider modifications to their solution(s) based on the information gathered during the tests and presentation. Teams review the original need or problem to ensure their modifications still meet the necessary criteria and constraints, and restart the EDP cycle.

THE ENGINEERING DESIGN PROCESS



This Engineering Design Process model was adapted from the Massachusetts Science and Technology/Engineering Curriculum Framework (published October 2006, http://www.doe.mass.edu/frameworks/scitech/1006.pdf).

STANDARDS ADDRESSED

Next Generation Science Standards	Common Core State Standards Mathematics
Practices 1. Asking questions, defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using math and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information *Cross-Cutting Concepts* 1. Patterns 2. Cause and effect 3. Scale 4. Systems and system models 5. Energy and matter 6. Structure and function *Core and Component Ideas* Physical Science PS2: Motion and Stability PS2.A: Forces and motion PS2.B: Types of interactions Earth and Space Science ESS1.B Earth and the Solar System *Engineering, Technology, and Applications of Science* ETS1.A: Defining and delimiting an engineering problem ETS1.B: Developing possible solutions ETS1.C: Optimizing the design solution ETS2.A: Interdependence of Science, Engineering, and Technology	*Standards for Mathematical Practice* MP1: Make sense of problems and persevere in solving them MP2: Reason abstractly and quantitatively MP3: Construct viable arguments and critique the reasoning of others MP4: Model with mathematics MP5: Use appropriate tools strategically MP6: Attend to precision Grades 6-8 *Expression and Equations* – Reason about and solve one- variable equations. Represent and analyze quantitative relationships between dependent and independent variables *Geometry* – Solve real-world and mathematical problems involving area, and surface area *Statistics and Probability* – Develop understanding of statistical variability. Summarize and describe distributions

BACKGROUND INFORMATION: PRESSURE SUITS

How Would the Human Body React to the Vacuum of Space?
While there is no visible delineation between the Earth's atmosphere and space, it is generally agreed that space begins 100 km (62 miles) above the Earth's surface. The effects of high-altitude exposure, however, begin well below this mark. At approximately 16 km (10 miles) in altitude, the air pressure is lower because there is very little air to breathe, which impedes the normal functions of the human body. Cells and tissues in the body start to lose oxygen, causing a condition known as hypoxia. Hypoxia leads to impaired judgment and ability to concentrate, loss of night-vision acuity, shortness of breath, nausea, and fatigue.

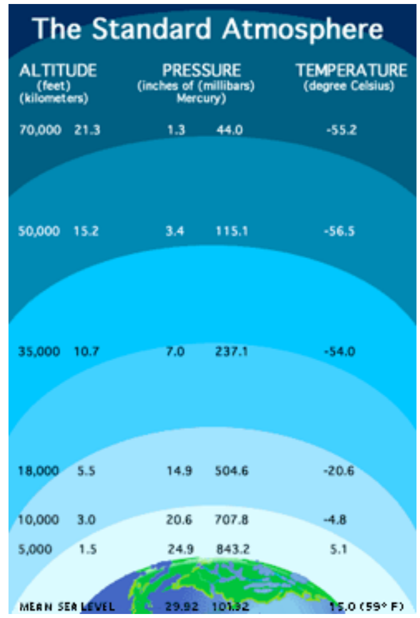


Figure 3: The standard atmosphere—a generally accepted average of the Earth's conditions for all latitudes, altitudes, and seasons.

When sudden decompression occurs, humans would have only 5 to 10 seconds to correct the situation. There would likely be some degree of consciousness for the first 9 to 11 seconds, but the human brain would be highly impaired after 13 seconds. As a result, high-altitude pilots and astronauts are trained to react quickly to try to help themselves and others in these situations. To reduce public risk, the Federal Aviation Administration requires that an oxygen supply is available if the plane's cabin pressure is reduced to the pressure at 15,000 feet (about 4.6 kilometers) above sea level or less.


Figure 4: The Earth's thin atmosphere revealed on the horizon seen from the International Space Station (NASA)

High in the atmosphere or in space, water in the nose and mouth will begin to boil because of lack of pressure. This water vapor rushes out of the body and rapidly cools the mouth and nose tissues to near-freezing temperatures. Soon after that, the liquid water in soft tissues and the circulatory system that lines the lungs will also boil and make the body swell. Because skin is strong and porous, air will gradually leak out through the skin rather than cause the body to burst.

As long as blood circulates through the body, the pressure of the circulatory system will keep the water in the blood below its boiling point. Within one minute of vacuum exposure, the heart will stop pumping, causing blood to stop circulating and eventually boil.

Humans will not instantly freeze solid as some movies have shown. Body heat will not rapidly deplete because of the insulative property of space (there are very few molecules to transfer heat energy). This concept works on Earth in vacuum-insulated bottles and windows, which are manufactured by drawing and sealing a vacuum between the inner and outer layers.

Why Pressure Suits?

The Human Body Needs a Pressure Suit.
Many years of research to help humans survive and function in low-pressure situations have taken place because the human body is so vulnerable in low-pressure environments. In 1966, Jim LeBlanc, a technician at NASA's Manned Spacecraft Center (now Johnson Space Center), was inadvertently exposed to a near-vacuum environment while testing a space suit prototype. A hose supplying oxygen disconnected from the suit, causing it to depressurize. LeBlanc remained conscious for about 14 seconds before passing out. Once the chamber was safely repressurized, he regained consciousness. LeBlanc reported later that as he was losing consciousness, he heard air leaking from his body and felt the water on his tongue begin to boil.

Figure 5: Jim LeBlanc in the vacuum chamber before losing consciousness. (NASA)

Pressure suits need to provide everything required for survival in low-pressure environments including space. Suits for high-altitude pilots and astronauts must be functional, allowing the user to operate machine controls and other equipment, as well as protective. Suits for pilots are pressurized with normal air to reduce the dangers associated with the flammability of pure oxygen. Suits for Astronauts are self-contained living environments that have systems incorporated into the suit to provide oxygen, water, air pressure, and regulate temperature. Extra layers protect astronauts from micrometeoroids (small particles of rock flying at intense speeds) outside of the spacecraft.

Figure 6: NASA's Z-2 space suit illustration. (NASA)

The Z-2 suit, NASA's newest prototype for astronauts to live and work on Mars, incorporates many advances over previous models. The most significant advance is a hard composite upper torso which provides more long-term durability that a planetary Extravehicular Activity (EVA) suit.

For more information visit:

- "A Pilot's Life at 65,000 Feet over Alaska" – http://earthobservatory.nasa.gov/blogs/fromthefield/2014/07/28/a-pilots-life-at-65000-feet-over-alaska/
- "Advanced Suit Development" – http://www.nasa.gov/exploration/technology/advanced_space_suits/

SAMPLE TIMELINE

The EDC must be completed within the eight-week challenge period. The following timeline serves as a suggestion for the eight-week implementation. You may structure the sessions to fit your needs.

EDC Weeks	EDP	Actions
Pre-EDC	Pre-EDP	Attend training and order materials
Week 1	Step 1 Step 2 Step 3	Identify the Need or Problem Research the Need or Problem Develop Possible Solution(s)
Week 2	Step 4 Step 5	Select the Best Solution Construct a Prototype
Week 3	Step 6 Step 7	Test and Evaluate Solution Communicate Solution
Week 4	Step 8 Step 1 Step 2	Redesign Identify the Need or Problem Research the Need or Problem
Week 5	Step 3 Step 4	Develop Possible Solutions Select the Best Solution
Week 6	Step 5 Step 6	Construct a Prototype Test and Evaluate Solution
Week 7	Step 7 Step 8	Communicate Solutions (compare iterations) Redesign (recommendations for the future)
Week 8	Post-EDP	Create and upload student videos

SAFETY

Safety is an important goal for all curricular areas of education. Safety issues are a special concern for STEM-based activities and courses. Many national and state academic standards address the need for schools and subject areas to promote student development of knowledge and abilities in a safe learning environment.

It is the responsibility of the school's administration, teachers, and facilitators to provide a learning environment that is safe, up-to-date, and supportive of learning. Additionally, facilitators are responsible for their students' welfare in the classroom and laboratory. Facilitators must be knowledgeable and diligent in providing a safe learning environment. Students should receive safety instructions relevant to the topics being taught. Assessments must accompany the lessons on safety, and records must be kept on student results. The facilitator must properly supervise students while they are working. The facilitator must inspect and maintain equipment and tools to ensure they are in proper working condition. Parents should be informed that a safe environment exists during the program. The facilitator should keep all students safe and assure that a safe environment exists and that proper procedures are being followed in the classroom and laboratory.

Students should:

1. Demonstrate respect and courtesy for the ideas expressed by others in the group.
2. Use tools and equipment in a safe manner and assume responsibility for their safety, as well as for the safety of others.
3. Make safety a priority during all activities.
4. Wear safety goggles when conducting the EDC.

Facilitators should:

1. Approve all drawings before students start building their designs.
2. Look for potentially hazardous combinations of materials and flimsy designs of structures.
3. Be sure resources are clean and dry with no sharp edges.
4. Be the only ones using hot-glue guns and sharp instruments.
5. Make sure all materials are not damaged or in disrepair.
6. Prohibit students from bringing in or using additional materials for their designs without prior approval.

FACILITATOR PAGES

USING A KLEW CHART

FACILITATOR DIRECTIONS: This KNOW, LEARN, EVIDENCE, WONDER (KLEW) chart can be used as a starting point for science investigation. Before you start the challenge, students should complete the **KNOW** section of this chart. It will allow students to share their prior knowledge and experiences, whether accurate or inaccurate. Complete the **LEARN** section after students are given background information about the Moon and lunar plant growth. This background information may come from videos, articles, and other supplemental information. Use the **EVIDENCE** section to help students reinforce concepts they learned using the background information and during the challenge by providing supporting information to validate what they stated in the LEARN column. Students share any new questions they may still want to explore in the **WONDER** section.

Please allow students to have flexibility in their answers. There are no right or wrong answers as long as the students answer the questions. Questions can be modified at the discretion of the Facilitator.

KNOW	LEARN	EVIDENCE	WONDER
What do I know about altitude, air pressure, and pressurized suits?	**What did I learn about altitude, air pressure, and pressurized suits based on my research?**	**What evidence do I have that supports what I learned about altitude, air pressure, and pressurized suits?**	**What am I still wondering about altitude, air pressure, and pressurized suits?**
Students should complete this column before researching about altitude, air pressure, and pressurized suits.	Students should complete this column after researching about altitude, air pressure, and pressurized suits.	Students should complete this column using supporting information from articles, background information research, direct observation, and SME connections.	Students should complete this column as they move through the process to document questions.

THE ENGINEERING DESIGN CHALLENGE

You will be using the Engineering Design Process (EDP) to solve the challenge problem. The following pages will help you guide the students through the Challenge. Break the students into teams of up to four students and follow each step of the EDP. Note that both the Facilitator pages and the student journal section are organized to align with the each step of the EDP.

THE CHALLENGE:

Pressure suits and space suits provide many layers of protection against the harsh environments of the upper-atmosphere and space. Because pilots and astronauts must complete their work in a near-vacuum or vacuum environment, suits must exert pressure on the body. All materials used to construct space suits must be tested in a vacuum to make sure they work in low-pressure environments.

Figure 7: Astronaut Rick Mastracchio, STS-118 mission specialist, wearing a space suit on the mission's first planned extravehicular activity. (NASA)

You will work in teams to design and build a pressure suit with the following criteria and constraints:

1. The suit must be constructed of materials that are not affected by the vacuum environment.
2. The suit must completely surround the pilot or astronaut (represented by a marshmallow) providing protection in a vacuum or near-vacuum environment.
3. The pilot or astronaut wearing the suit must fit completely within the vacuum chamber and have a total mass less than 50 grams.
4. The prototype design materials must cost less than $10.00.

MATERIALS

The following is a suggested list of materials needed to complete this challenge. The quantity will depend on the number of students participating. Alternatives can be used if necessary.

- Digital scale or balance (1)
- Vacuum pump (1)
- Vacuum jar (1)
- Rulers (1 per team)
- Large marshmallows (several per team to serve as test pilots or astronauts)
- General building supplies for teams to assemble their pressure suits. These could include:

aluminum foil
balloons
binder clips
bubble wrap
buttons or beads
cardboard or cardstock
clothespins
cloth
coffee filters
cotton balls
craft sticks or tongue depressors
empty paper towel or toilet paper tubes
glue sticks
masking, electrical, transparent and duct tapes
mini foil pie plates
modeling clay
paper bags
paper clips
pennies
pipe cleaners
plastic cups
plastic eggs
plastic wrap
rubber bands
scissors
skewers or stirrers
staplers and staples
straws
string

Pre-Activity Set-Up:

- Acquire a vacuum pump that is safe and in good working condition. You could use a food saver vacuum or a tube beaker with stopper and syringe as an alternative.

- Determine a unit cost for each of the materials available and decide the maximum budget each team has to design their model. This value can be raised (budget increase) or lowered (budget cut) to adjust the level of challenge difficulty. Teams should itemize their budget using the Budget Planning Worksheet on page 37.

STEP-BY-STEP FACILITATION INSTRUCTIONS

Introduce the Challenge

Provide students the information covered in the challenge description found on page 15. Use the Challenge Rubric on page 25 in the student journal section to show students how their work during this challenge will be evaluated.

The Engineering Design Process Steps with Guiding Questions

STEP 1: Identify the Need or Problem

- Facilitate learning by asking the following guiding questions:
  - How can our team design a _____ that will _____?
  - What needs to be solved/improved?
  - What are we trying to accomplish?
- Review the Engineering Design Process with the students.
- Show the NASA Beginning Engineering Science and Technology (BEST) video titled "Repeatability" found at https://www.youtube.com/watch?v=-2Az1KDn-YM.
- Ask students why it is important to test their own designs.
- Ask students to identify the specific criteria and constraints of the design challenge. You will work in teams to design and build a pressure suit constructed of materials that are not affected by the vacuum environment. The suit must completely surround the pilot or astronaut (represented by a marshmallow) providing protection in a vacuum or near-vacuum environment. The pilot or astronaut wearing the suit must fit completely within the vacuum chamber and have a total mass less than 50 grams. The prototype design materials must cost less than $10.00.
- Have team members fill out Step 1 on page 28 in the student journal section.

STEP 2: Research the Need or Problem

- Facilitate learning by asking the following guiding questions:
  - Where can you find more information about the topic?
  - What questions could you ask an expert?
- Help students answer any questions they have about the challenge. Use the Internet or a school library to research answers. Sample resources have been provided in the NASA Resources section on page 39. Any unanswered questions should be written down and saved to ask during the NASA SME connections.
- Have team members fill out the Step 2 on page 29 in the student journal section.

STEP 3: Develop Possible Solutions

- Facilitate learning by asking the following guiding questions:
  - What are all the ways your team can imagine to solve this?
  - What do we need to do to add _____ to the design?
  - What might go wrong if we add _____ to the design?

- Ask each team member to brainstorm, make sketches representing their ideas for a solution, and clearly label and identify each part of their drawing.
- Each team member should make sure that designs meet all constraints and criteria.
- Have students complete Step 3 on page 30 in the student journal section.

STEP 4: Select the Best Possible Solution(s)

- Facilitate learning by asking the following guiding questions:
  - Would it be better to _____ or _____?
  - Can we combine more than one plan?
  - Would a _____ fulfill the constraints of the challenge?
  - Do we have the resources to build a _____?
- Each team member will discuss their ideas and drawings with the rest of the team.
- The students will record the strengths and weaknesses of each of the designs.
- Have students fill out Step 4 on page 31 in the student journal section.

STEP 5: Construct a Prototype

- Facilitate learning by asking the following guiding questions:
  - What resources does your team need to gather?
  - What is the plan?
  - Who is doing what?
- Ask each team to identify the design that appears to solve the problem.
- A final diagram of the design should be precisely drawn and labeled with a key.
- Each team is to determine what materials they will need to build their design and assign responsibilities for each team member for prototype completion.
- The final drawings should be approved by the facilitator before building begins.
- Teams will receive the materials they will need to build their model and complete a budget sheet representing the cost of their model.
- Using the drawings, the teams are to construct their prototypes.
- Have teams complete Step 5 on page 32 in the student journal section.

STEP 6: Test and Evaluate the Solution(s)

- Facilitate learning by asking the following guiding questions:
  - How did the prototype perform when tested?
  - Was the design successful?
- Visit each team and test their designs to ensure they are adhering to all criteria and constraints of the challenge.
- Each team will insert a pilot or astronaut (marshmallow) into the pressure suit, test the model inside the vacuum chamber, and record the results of the test. Tests will often result in suit failure requiring a new suit to be built.
- Have teams fill out page 33 in the student journal section.

STEP 7: Communicate the Solution(s)

- Facilitate learning by asking the following guiding questions:
  - What did or did not work? Why?
  - What are the pros and cons of this solution?
- Ask team members to document and report the results of their designs, identify what changes were made with each iteration, and what the team believed caused the design to succeed or fail during the tests.

- Have teams fill out one row of page 34 in the student journal section.

STEP 8: Redesign

- Facilitate learning by asking the following guiding questions:
    - How did the prototype perform when tested?
    - What did and didn't work?
    - What could be improved in the next iteration of this design?
- Ask teams to identify the causes of any problems that were observed during testing and to consider possible modifications to solve these problems.
- Have teams check that their redesigned model still meets all the criteria to solve the problem.
- Have teams complete Step 8 on page 35 in the student journal section.

From here on, the cycle will repeat with redefined problems and redesigned solutions as often as time and resources allow. Depending on the amount of redesign students put into each iteration, some steps may only need a quick revisit to be sure students are on track, while some steps will need to be completely redone. **In those cases, additional copies of cycle step pages should be made and added into the student journal section.**

Submit Final Design

On the last design iteration, use the documentation from Step 7 to create a video of the design development and final design solution according to the Video Criteria and Video Rubric found on pages 26 and 27. Also, use the Engineering Design Process worksheet on page 23 to test student knowledge of the entire design cycle.

STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What were the greatest challenges for your team through this process?

2. What strategies did your team prove effective in overcoming your greatest challenge?

3. How did you use the Engineering Design Process to help you with your design?

4. Which suit design provided the most reliable results?

5. Which suit design protected the astronauts the most?

6. Which materials and design worked best in this challenge?

CHALLENGE CHECKLIST

PRIOR TO THE CHALLENGE

Things to download, print, review, and copy:

- ❑ 1. Download and review the presentation slides for students.
- ❑ 2. Download, print, and review the Video Criteria and Rubric. Make a copy for each team of students.
- ❑ 3. Download, print, and review the Educator Guide, Packing Up for the Moon. Print the student journal pages for each team.
- ❑ 4. Download or bookmark the introductory video, Telling Our Story with Video, and any other videos needed for your presentation.
- ❑ 5. Download and review the Technical Requirements for the Video.
- ❑ 6. Download, review, and print enough media release forms for each student.

Things to schedule, set up, or test:

- ❑ 1. Review the online Event Schedule and select at least one live event for students to interact with a NASA Subject Matter Expert.
- ❑ 2. Gather and organize materials from the materials list for each activity.
- ❑ 3. Test your technology set up to make sure students can see and hear videos, slides, etc.
- ❑ 4. Check your video or digital cameras to ensure they are fully charged and have enough memory or tape for recording challenge activities.

During the Challenge

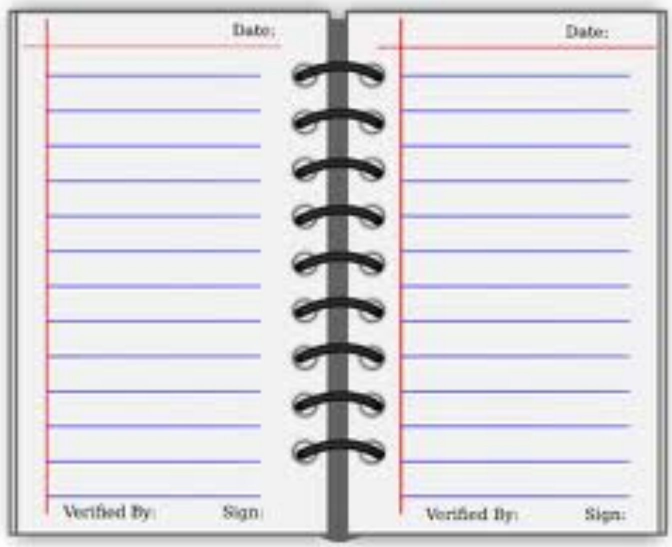
- ❑ 1. Distribute media release forms to each participating student and set a due date for return.
- ❑ 2. Ask each group of students to come up with a unique team name.
- ❑ 3. Use the presentation slides for students to lead the students through the challenge.
- ❑ 4. Encourage each team to take pictures and video throughout the challenge for use in their final video.
- ❑ 5. Help students prepare questions and information to share with NASA Subject Matter Experts during the live event for students.
- ❑ 6. Participate in one or more live events for students.

After the Challenge

- ❑ 1. Review Video Criteria and Rubric and Telling Our Story with Video with students.
- ❑ 2. Assist students as they plan and create their final video.
- ❑ 3. Upload student video submissions.
- ❑ 4. Allow enough time to send a separate email with entry information and media release forms for each video by April 16, 2015.
- ❑ 5. Participate in the evaluation of the 21CCLC pilot Program.

Student Name: ___________________ **Team Name**___________________

STUDENT TEAM CHALLENGE JOURNAL

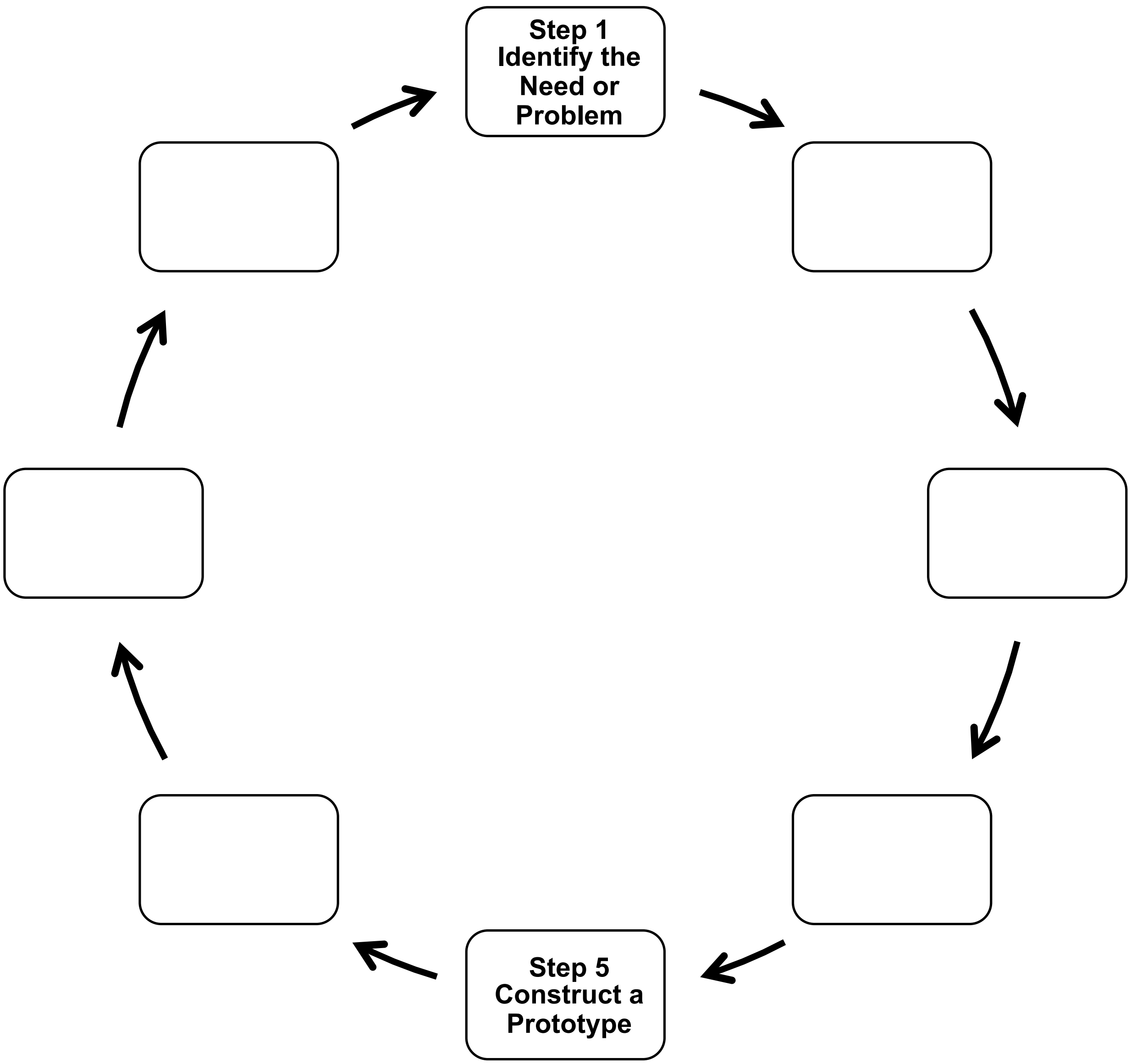


ENGINEERING DESIGN PROCESS

Directions for the Students: Can you determine the sequence that engineers take to make a completed design? On your own, try to label the steps of the Engineering Design Process. Put the rest of the steps below in order based on the two that have already been filled in for you.

Research the Need or Problem
Test and Evaluate the Solution(s)

Select the Best Possible Solution(s)
Communicate the Solution(s)
Develop Possible Solution(s)
Redesign



KLEW CHART FOR STUDENTS

Student Name: ____________________ **Team Name**____________________

This Challenge is: _______________________________

KNOW	LEARN	EVIDENCE	WONDER
What do I know about altitude, air pressure, and pressurized suits?	**What did I learn about altitude, air pressure, and pressurized suits based on my research?**	**What evidence do I have that supports what I learned about altitude, air pressure, and pressurized suits?**	**What am I still wondering about altitude, air pressure, and pressurized suits?**

CHALLENGE RUBRIC

Use the rubric below to assess each team's final design. It may be helpful to have each group explain how they applied Steps 1 to 8 in the Engineering Design Process to create their designs.

Category	Below Target (1)	At Target (2)	Above Target (3)
1. Identifying the Need or Problem	Rephrases the need or problem with limited clarity and fails to identify criteria or constraints.	Rephrases the need or problem clearly and identifies most criteria and constraints.	Rephrases the need or problem precisely and identifies all criteria and constraints.
2. Research the Need or Problem	The need or problem is not well researched and will not be helpful in development of solutions.	The need or problem is adequately researched and may assist in development of solutions.	The need or problem is thoroughly researched and can easily direct development of solutions.
3. Develop Possible Solutions	Contributes implausible ideas or no ideas. Produces incomplete sketches. Does not present a concept.	Contributes a plausible idea. Produces marginally accurate sketches of design concepts.	Contributes multiple, plausible ideas. Produces accurate sketches of design concepts.
4. Selecting the Best Possible Solution(s)	Does not adequately analyze strengths and weaknesses of possible solutions. Does not select a solution based on need or problem criteria and constraints.	Satisfactorily analyzes strengths and weaknesses of possible solutions. Selects a solution based on some but not all need or problem criteria and constraints.	Thoroughly analyzes strengths and weaknesses of possible solutions. Selects a promising solution based on thorough analysis of all need or problem criteria and constraints.
5. Construct a Prototype	The prototype meets the task criteria to a limited extent.	The prototype meets the task criteria.	The prototype meets the task criteria in insightful ways.
6. **Test and Evaluate the Solution(s)**	Data is not taken accurately or does not reflect performance of the prototype.	Data is taken accurately that reflects the performance of the prototype.	Data is taken accurately that reflects the performance of the prototype and will clearly help in redesign.
7. **Communicate the Solution(s)**	Both test results are not accurately reported and areas of improvement are not shared.	Either test results are not accurately reported or areas of improvement are not shared.	Test results are accurately reported and areas for improvement are shared insightfully.
8. Redesign	Refinement is not evident based on prototype testing and evaluation results.	Refinements are made based on prototype testing and evaluation results.	Significant improvement in the design is made based on prototype testing and evaluation.

Total score: ____________________

Team name: ____________________

VIDEO CRITERIA AND VIDEO RUBRIC

Video Criteria

Use the rubric below to guide students in creating their video submission and assessing their final video product. It will be used by evaluators to review and score each submitted video based on the above criteria and presentation style:

1. Teams MUST use the following script to introduce their video:
    a. "This is team (team name) and we worked on the *Why Pressure Suits*? challenge. The title of our video is ____________________."
    b. Do not identify the name of any student, teacher, school, group, or city/region in your video. Submissions that do not follow these directions will be disqualified.
2. Based on your results and modifications, explain your best design solution from Step 4. Be sure to give reasons for your choice.
3. Introduce special features and unique qualities of your design.
4. Discuss the results of tests from Step 6 and modifications made to improve the device from Step 8 for each design iteration.
5. Include photos or video of a summary of your work including drawings of your design, key measurements, and how the prototype was built and tested.
6. Identify any information provided by NASA SMEs that helped you in your design or testing.
7. Explain which characteristics of your design provided the most reliable results and why?
8. Based on your results and the modifications you recorded in Step 7, include advice for the engineers working on this project in the future.
9. The total length of video should be three to five minutes.

Video Rubric

Student Name: ___________________ **Team Name**___________________

This rubric can be used to review and assess the quality of each video. Each category will be scored 0-3 points. Totals for each column will be added for a final score.

Category	Best = 3 points	Better = 2 points	Good = 1 point	Missing = 0 points
Introduction Statement	Special features are clearly stated with additional words and/or images.	Special features are stated but no additional images are included.	Special feature statement is incomplete.	No statement is included.
Drawings	A detailed drawing of the final design and detailed drawings of each iteration are included.	A detailed drawing of the final design is included but not other iterations.	Rough drawings of the final design or other iterations are included.	No drawings are included.
Engineering design process	All EDP phases are mentioned.	More than four elements of the EDP are mentioned.	At least one element of the EDP is mentioned.	The EDP is not mentioned.
NASA subject matter expert (SME) comments	Interactions with NASA engineers and scientists are discussed and show how the feedback was incorporated into design or testing.	Interactions with NASA engineers and scientists are discussed and gives details about the feedback they provided.	Interactions with NASA engineers and scientists are discussed in only general terms.	NASA engineers and scientists interactions are not mentioned.
Video criteria	All criteria are addressed thoroughly and thoughtfully.	Criteria are addressed.	Some criteria are addressed.	Criteria are not addressed.
Photos or video	Video of the build and test phases are included with additional still shots added.	The build and test phases are included in the photos and video.	Only the build *or* only the test phase is included in the photos and video.	Photos and video showing the build or test phases are not included.
Column score				

Total Score: ______________________

STEP 1: IDENTIFY THE NEED OR PROBLEM

The Challenge:

Pressure suits and space suits provide many layers of protection against the harsh environments of the upper-atmosphere and space. Because pilots and astronauts must complete their work in a near-vacuum or vacuum environment, suits must exert pressure on the body. All materials used to construct space suits must be tested in a vacuum to make sure they work in low-pressure environments.

Figure 8: Astronaut Rick Mastracchio, STS-118 mission specialist, wearing a space suit on the mission's first planned extravehicular activity. (NASA)

You will work in teams to design and build a pressure suit constructed of materials that are not affected by the vacuum environment. The suit must completely surround the pilot or astronaut (represented by a marshmallow) providing protection in a vacuum or near-vacuum environment. The pilot or astronaut wearing the suit must fit completely within the vacuum chamber and have a total mass less than 50 grams. The prototype design materials must cost less than $10.00.

Based on this information and the challenge introductory video, answer the following questions.

1. Using your own words, restate the problem in the form of "How can I design a ____________ that will ____________?" Be sure to include all expected criteria and constraints.

____

____

____

____

2. What general scientific concepts do you and your team need to consider to begin solving this need or problem?

____

____

STEP 2: RESEARCH THE NEED OR PROBLEM

Conduct research to answer the following questions related to the challenge problem. Cite where you found your information on the Source(s) lines below.

1. Who is currently working on this or a similar problem today? What solutions have they created or are working on currently?

Source(s):

2. What questions would you ask an expert who is currently trying to solve problems like this one?

3. Who in our society will benefit from this problem being solved? How could this relate to everyday use?

Source(s):

4. What are some innovative options for using the materials that are available to solve this challenge?

Source(s):

STEP 3: DEVELOP POSSIBLE SOLUTIONS

Sketch your suit design in the space below and label each part of your drawing. Consider the following questions when brainstorming your ideas.

What shape do you think the pressure suit or space suit should be?
What special features would your design have?
What materials could you use to design your suit?
Are all the criteria and constraints being met by these ideas?

STEP 4: SELECT THE BEST POSSIBLE SOLUTION(S)

Work with your team to analyze each person's final drawing using the table below. Based on the team's discussions, determine which design will be used to solve the problem, and what features will be included to create team's prototype.

Design # Designer Name	Does this design meet all criteria and constraints of the problem?	What are the strong elements of this design?	What elements need to be improved?
1.			
2			
3			
4			

STEP 5: CONSTRUCT A PROTOTYPE

1. Make a final drawing of your prototype. Have it approved by your facilitator.

Approved by: ______________________________

What are the resources that will need to be gathered?

____

____

____

____

Who in the group is doing what?

Team Member				
Responsibilities in the building process?				

STEP 6: TEST AND EVALUATE THE SOLUTION(S)

Using the materials provided, build and test your model. Be sure to record the data from each of your trials.

1. Record the mass and calculate the surface area of the drag device below. Show your calculations.

   Total Mass ______________________

   Total Cost ____________________________

2. Insert your pilot or astronaut inside the suit and into the vacuum chamber. Draw a vacuum and carefully observe any changes to the suit or the astronaut. For each change record the pressure of the vacuum system at that time using appropriate units such as pounds per square inch, Newtons per square meter, number of draws of the syringe, or time into the test if the vacuum being pulled is constant.

Pressure or time into test	Suit observations	Pilot or astronaut observations

STEP 7: COMMUNICATE THE SOLUTION(S)

It is not enough to produce raw data. Scientists and engineers need to interpret the data so that they can convince others that their results are meaningful. This step will help you summarize how your design changed through multiple iterations of the engineering design process. Fill out the table below using information from your initial prototype.

Iteration #	What are the key components to your initial prototype?	What do you think caused the design to succeed or fail during testing and why do you think that?
1		

All modifications to your design, both major overhauls and minor tweaks, should be recorded below to track the changes made. After every phase of tests, complete the chart below by describing changes and summarizing what results the testing showed.

Iteration #	What was added, removed, or changed in this iteration of your design?	What do you think caused the design to succeed or fail during testing and why do you think that?
2		
3		
4		
5		

STEP 8: REDESIGN

Did this iteration of your design meet all of the constraints of the original problem? ____________

What problem(s) did you discover while testing this iteration?

What will you do to try to improve your design based on this data?

How do you predict that these changes will improve over the iteration you just tested?

STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What were the greatest challenges for your team today?
2. What strategies did your team prove effective in overcoming your greatest challenge?
3. How did you use the Engineering Design Process to help you with your design?
4. Which suit design provided the most reliable results?
5. Which suit design best protected the astronauts?
6. Which materials and design worked best in this challenge?

BUDGET PLANNING WORKSHEET

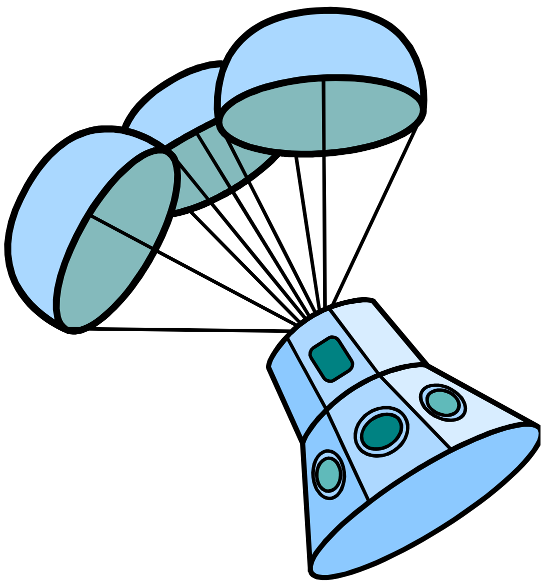
Team Name: ___________________

Directions: As a team, complete the cost sheet below. Be sure to include all of the materials that are needed, quantity, unit cost (determined by your facilitator), and the final total to complete your design. Try to use the least amount of materials to keep the cost of your design low.

Line item number	Material	Unit cost	Quantity	Item total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Total cost ____________

SUPPORT MATERIALS



NASA RESOURCES

Videos

What is Atmospheric Pressure? – *http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/What_is_Atmospheric_Pressure.html*

The Construction and Design Elements of Spacesuit Technology – *http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/The_Construction_and_Design.html*

Space suits – NASA's Do-It-Yourself Podcast (video playlist) – *http://www.nasa.gov/audience/foreducators/diypodcast/ss-video-index.html*

Websites

Interactive Spacesuit Experience – *http://www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit.html*

Dressing for Altitude – *http://www.nasa.gov/connect/ebooks/dress_for_altitude_detail.html*

NASA Quest – The Outer Space Environment – *http://quest.nasa.gov/space/teachers/suited/3outer.html*

A Brief History of the Pressure Suit – *http://www.nasa.gov/centers/dryden/research/AirSci/ER-2/pshis.html*

Spacesuits and Spacewalks – *http://www.nasa.gov/audience/foreducators/spacesuits/home/index.html*
http://spaceplace.nasa.gov/mars-adventure/en/

Suited for Spacewalking Educator's Guide – *http://www.nasa.gov/pdf/143159main_Suited_for_Spacewalking.pdf*

For more information and to access the Help Desk, visit the 21CCLC NASA STEM Challenge website at http://y4y.ed.gov/stemchallenge/nasa.

EXTENSION ACTIVITIES

Activity One: Marshmallows in a vacuum chamber

The human body would swell if it were not contained in a pressure suit or space suit when exposed to high altitudes over the earth or to the vacuum of space. Since large marshmallows also expand in a vacuum this activity will demonstrate what the human body would do without a suit.

Materials

- Vacuum pump and jar
- Large marshmallows (fresher marshmallows produce the most dramatic results.)
- Scale or balance
- Student journals
- Goggles

Procedure

1. All students **must** wear goggles for this activity, especially when the vacuum chamber is in use.

2. Ask students what they think will happen when the marshmallow is placed in a vacuum and why. Have them record their answers in their journals.

3. Have students record the mass of the marshmallow in their journals.

4. Place the marshmallow in the vacuum chamber. Turn on the vacuum pump and have students observe the difference in the size of the marshmallows. Ask students to discuss why they think the marshmallow is changing shape. Have students record all observations in their journals.

5. Turn off the pump when the marshmallow stops increasing in size and repressurize the chamber. Have students observe what happens to the marshmallow during repressurization. Explain that the air has been pulled out of the marshmallow during the vacuum process. Ask the students to explain why the marshmallows shriveled once the air pressure was reintroduced. Have students record the new mass of the marshmallow and all observations in their journals.

Activity Two: Balloons in a vacuum chamber

Balloons, like the marshmallows, will expand in a vacuum. Your skin and your lungs are similar to balloons in that they can expand and stretch, but only so far before rupturing. Place a small balloon inside the vacuum chamber to show students what could happen to your lungs high in the atmosphere or in space.

Materials

- Vacuum pump and jar
- 2 Medium-sized balloons (clear or translucent is recommended)
- Water
- Scale or balance
- Student journals
- Goggles

Procedure

1. All students must wear goggles for this activity, especially when the vacuum pump is in use.

2. Partially inflate the balloon leaving plenty of room for the balloon to expand inside the vacuum chamber. Tie a knot in the neck of the balloon to keep it from deflating.

3. Find the mass of the partially inflated balloon, and have students record it in their journals.

4. Place the balloon inside the vacuum chamber. Turn on the vacuum pump and ask students to observe and record what happens to the balloon in a vacuum.

5. Turn off the pump before the balloon bursts or fills the entire chamber and repressurize the chamber. Remove the balloon from the chamber and once again measure and record the mass of the balloon. There should be no change in mass from the initial measurement, indicating that no air has been added to or removed from the balloon during the vacuum process.

6. Add a small amount of water to the inside of another balloon and repeat the vacuum process. When a high-enough vacuum is drawn, the water will begin to boil which can be easily observed inside a clear balloon. This would be similar to what would happen to the water in your lungs and can be seen if you use a transparent balloon. Note that if the balloon breaks during the test, water will spill into the vacuum chamber. Stop the vacuum pump immediately to prevent the water from being drawn into the vacuum pump.

Activity Three: Testing building materials in a vacuum chamber

Like the marshmallows and water balloons, the materials that are used in the flight suit or space suit will also need to be tested in a vacuum because each material will react differently. Place the various building materials inside the vacuum chamber individually to demonstrate what could happen to them in space.

Materials

- Vacuum pump and jar
- Building materials used in the *Why Pressure Suits* design challenge
- Scale or balance
- Student journals
- Goggles

Procedure

1. All students must wear goggles for this activity, especially while the vacuum chamber is in use.

2. Place each of the building materials inside the vacuum chamber individually. Be sure to leave plenty of room for expansion in the jar.

3. Turn on the vacuum pump and ask students to observe and record what happens to each of the building materials in the vacuum.

4. Some building materials respond differently when they are exposed to a vacuum environment by themselves compared with when they are a part of a more complex pressure suit design. For example, placing duct tape in the vacuum chamber by itself might not reveal that it does not seal well in a vacuum because of the pores in the tape. Students need to closely examine the building materials for potential strengths and weaknesses and record their observations in their student journals.

6. Turn off the pump when students determine that no further changes are occurring to each material at lower pressure. Repressurize the chamber and have students observe what happens to each material during repressurization and record any observations in their journals.

GLOSSARY OF TERMS

Air density – the amount of air per unit measure in an area

Air pressure – the force exerted on you by the weight of tiny particles of air

Atmospheric pressure – the external pressure of the atmosphere

Capstan tubes – inflatable tubing that provides additional pressure when necessary

Constraints – the limits placed on the design due to available resources and environment

Criteria – standards by which something may be judged or decided

Hypoxia – an inadequate oxygen supply to the cells and tissues of the body

Iteration – one cycle of a repetitive process

Prediction – the act of attempting to tell beforehand what will happen

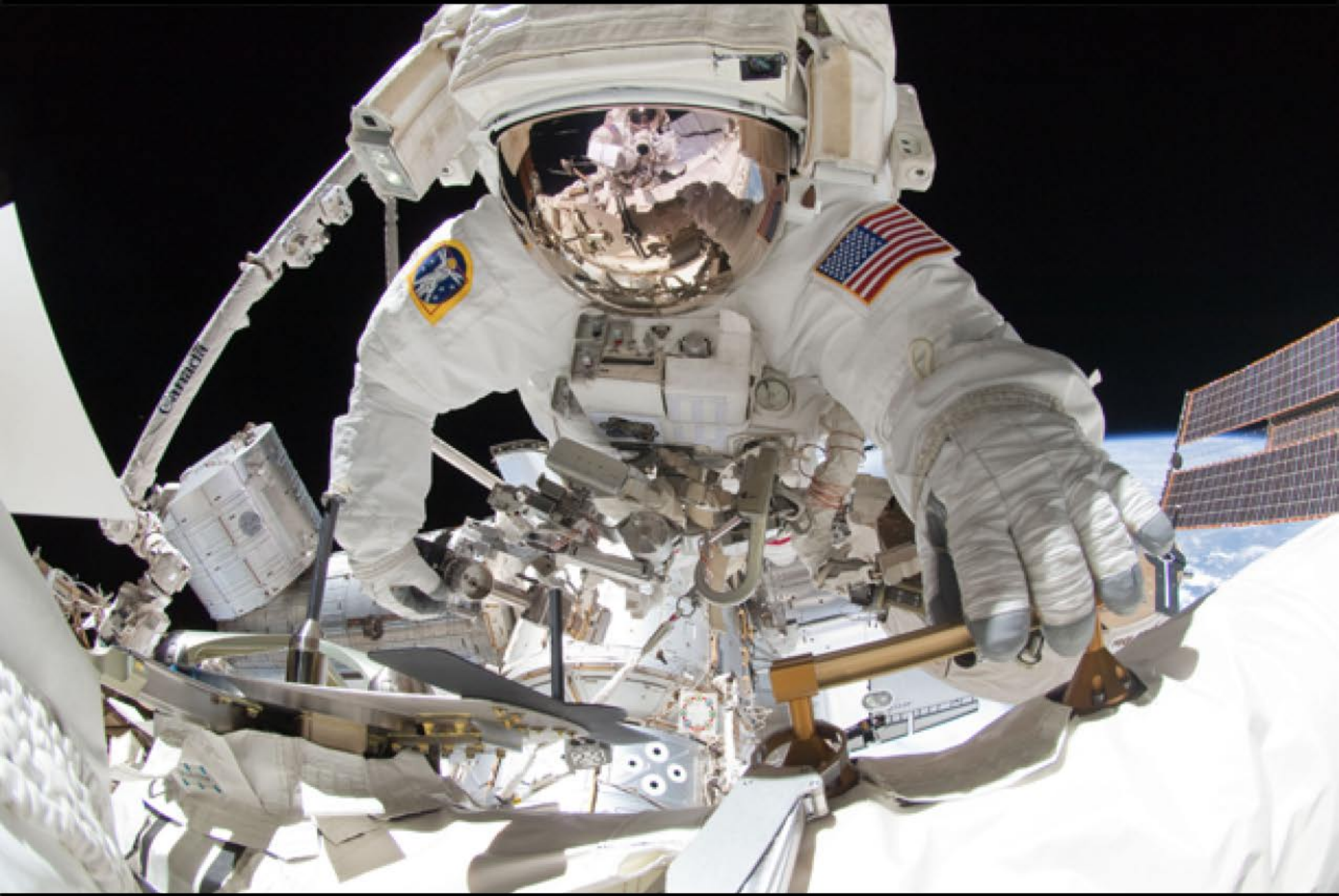
Space suit – a self-contained living environment for pilots and astronauts that consists of everything needed for short-term survival including breathing oxygen, pressure exerted on the body, and a heating and cooling system

Template – a pattern used to guide in making something accurately

Vacuum – the nearly total absence of gas molecules

Vacuum chamber – a rigid enclosure from which air and other gases are removed, resulting in a low-pressure, space-like environment

Vacuum pump – a mechanical device used to draw air out of a chamber, creating a low pressure environment



"The most important thing we can do
is inspire young minds and to advance the kind of science, math and technology education that will help youngsters take us to the next phase of space travel."

Senator John H. Glenn, Jr.,
NASA Astronaut and United States Senator

National Aeronautics and Space Administration

John H. Glenn Research Center
21000 Brookpark Road
Cleveland, OH 44135

www.nasa.gov

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